Improved outcomes with peritoneal dialysis catheter placement after cardiopulmonary bypass in infants

David M. Kwiatkowski, MD,[a] Shina Menon, MD,[b] Catherine D. Krawczeski, MD,[a,b] Stuart L. Goldstein, MD,[a,b] David L. S. Morales, MD,[a] Alistair Phillips, MD,[a] Peter B. Manning, MD,[c] Pirooz Eghtesady, MD, PhD,[c] Yu Wang, MS,[a] David P. Nelson, MD, PhD,[a] and David S. Cooper, MD[a]

Background: Acute kidney injury (AKI) is common in infants after cardiopulmonary bypass and is associated with poor outcomes. Peritoneal dialysis improves outcomes in adults with AKI after bypass, but pediatric data are limited. This retrospective case-matched study was conducted to determine if the practice of peritoneal dialysis catheter (PDC) placement during congenital heart surgery is associated with improved clinical outcomes in infants at high risk for AKI.

Methods: Forty-two infants undergoing congenital heart surgery with planned PDC placement (PDC+) were age-matched to infants undergoing similar surgery without PDC placement (PDC−). Demographic, baseline and outcome data were compared. Our primary outcome was negative fluid balance on postoperative days 1 to 3. Secondary outcomes included time to negative fluid balance, time to extubation, frequency of electrolyte corrective medications, inotrope scores, and other clinical outcomes.

Results: Baseline data did not differ between groups. The PDC+ group had a higher percentage of negative fluid balance on postoperative days 1 and 2 (57% vs 33%, $P = .04$; 85% vs 61%, $P = .01$). The PDC+ group had shorter time to negative fluid balance (16 vs 32 hours, $P < .0001$), earlier extubation (80 vs 104 hours, $P = .02$), improved inotrope scores ($P = .04$), and fewer electrolyte imbalances requiring correction ($P = .03$). PDC-related complications were rare.

Conclusions: PDC use is safe and associated with earlier negative fluid balance and improved clinical outcomes in infants at high risk for AKI. Routine PDC use should be considered for infants undergoing cardiopulmonary bypass. Further prospective studies are essential to prove causative effects of PDC placement in this population. (J Thorac Cardiovasc Surg 2015;149:230-6)

CHD

See related commentary on pages 237-8.

Acute kidney injury (AKI) is common in infants after surgical repair of complex congenital heart disease, occurring in 30% to 50% of patients.[1,2] Postoperative AKI is associated with significantly increased in-hospital mortality, longer intensive care unit and hospital stays, and prolonged need for mechanical ventilation and inotropic support.[2-6] Fluid overload has been shown to be an independent predictor of hospital stay, and severity of fluid overload is associated with worsening outcomes in children, including mortality.[7,8]

Fluid restriction and diuretics comprise the mainstay of fluid balance management in postoperative cardiac surgery patients, despite the increasing literature suggesting that peritoneal dialysis is a safe and effective alternative.[9-12] In October 2010, our institution made a systematic practice change to electively place a peritoneal dialysis catheter (PDC) at the time of surgery in infants determined to be high risk for AKI based on cardiac anatomy, age, and expected cardiopulmonary bypass (CPB) time (Table 1). We compared outcomes between infants who had a PDC placed during surgery (PDC+) and age-matched infants with similar surgeries without the placement of a PDC (PDC−) to determine if PDC placement was associated with improved clinical outcomes and if there were adverse events attributable to PDC placement.

METHODS

Participants and Study Design

We performed a retrospective case-matched cohort study of our surgical experience to determine if clinical outcomes improved with planned placement of a PDC at time of surgery (PDC+ patients). Review of our institutional surgical database disclosed 55 infants with congenital heart disease less than 6 months of age who underwent corrective heart surgery

From the Heart Institute[a] and Center for Acute Care Nephrology,[b] Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio; and Division of Cardiothoracic Surgery,[c] St Louis Children's Hospital, St Louis, Mo.

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David M. Kwiatkowski and Shina Menon contributed equally to this work.

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Address for reprints: David M. Kwiatkowski, MD, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio (E-mail: david.kwiatkowski@cchmc.org).

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Abbreviations and Acronyms

AKI = acute kidney injury
CICU = cardiac intensive care unit
CPB = cardiopulmonary bypass
ECMO = extracorporeal membrane oxygenation
PDC = peritoneal dialysis catheter
RACHS = Risk Assessment in Congenital Heart Surgery
POD = postoperative day

with CPB and placement of a PDC between October 2010 and August 2012; these patients define the study group to which controls were matched.

Patients in the study group were matched with the most recent infant who underwent the same procedure without placement of a PDC (PDC− patients) from January 2007 to October 2010. Attempts were made to match neonates (age <1 month) within 1 week of age and other infants within 2 weeks of age at the time of surgery. The control pool sizes were small (<20) for specific procedures within age restraints, and propensity matching was not used. Within the single ventricle cohort, the dominant ventricle was matched when possible. Potential matched patients were excluded if they died on the day of surgery (n = 2) or were started on other extracorporeal support (eg, extracorporeal membrane oxygenation [ECMO] or continuous renal replacement therapy) immediately after bypass (n = 6). Infants who underwent uncommon surgical procedures were excluded due to lack of a control (n = 5). The resulting study population comprised 42 infants and their matched controls. The Cincinnati Children's Hospital Medical Center Institutional Review Board approved this study. Additional patient consent was not required as only existing data were reviewed.

Patient Management

Table 1 depicts the criteria for intraoperative PDC placement at the time of CPB. According to institutional protocol, a PDC was placed at the completion of CPB in patients deemed at high risk for AKI, including all infants younger than 3 months undergoing any CPB procedure or infants younger than 6 months undergoing heart transplant or younger than 4 months undergoing tetralogy of Fallot or double outlet right ventricle repair. Patients with prolonged CPB times (>120 minutes) had a PDC placed in the operating room at the surgeon's discretion. Patients had a preoperative consultation with the nephrology service when possible.

The pediatric Tenckhoff PDC (37 cm; Quinton Instrument Company, Bothell, Wash.) was inserted via direct transperitoneal access through a purse-string suture in the peritoneum at the inferior aspect of the sternotomy incision and brought out through a stab incision in the left or right upper quadrant. Routine intraoperative fluid management with continuous ultrafiltration and modified ultrafiltration was used. Use of CPB, regional cerebral perfusion, and deep hypothermic circulatory arrest was case specific and according to standard practice. Infants typically returned to the cardiac intensive care unit (CICU) on a milrinone infusion for afterload reduction and low-dose epinephrine for contractility. Calcium (to enhance contractility) and vasopressin (to increase systemic vascular resistance) were added as necessary based on hemodynamics. Dopamine and dobutamine are rarely used in our CICU.

All patients were managed postoperatively in the CICU. As standard, inputs were restricted to two-thirds maintenance volume during the first 2 postoperative days. Medication administration and ventilator support was at the discretion of the CICU physician team. Without a PDC, typical diuretic management begins with furosemide 1 mg/kg every 6 hours when adequate hemodynamics are achieved. Chlorothiazide is added on the first postoperative day as necessary. In patients with PDCs, furosemide is occasionally used before oliguria during drainage, and is always used as the patient is transitioned from dialysis to standard diuresis, typically on postoperative day (POD) 3 to 4. Decisions regarding management and removal of the PDC were made by the CICU team in consultation with the nephrology service. The initial peritoneal dialysis prescription was 10 mL/kg 1.5% Dianeal (Baxter Healthcare, McGaw Park, Ill) with potassium chloride (KCl) 2 to 3 mEq/L and unfractionated heparin 200 units/L; 5-minute fill, 45-minute dwell, 10-minute drain, continuous via Gesco setup (Utah Medical Products, Inc., Midvale, Utah). Peritoneal dialysis was typically started if urine output was less than 1 mL/kg/h for 4 to 8 hours and otherwise left clamped or to drain at the discretion of the CICU team. In efforts to minimize infection, the peritoneal dialysis system is a closed circuit which is replaced every 72 hours, with minimal handling of the circuit by trained dialysis nurses.

Study Variables

Baseline data included demographic information, primary cardiac diagnosis, age, surgical weight and length, and preoperative creatinine level. Intraoperative variables included surgical procedure performed and associated Risk Assessment in Congenital Heart Surgery (RACHS)-1 score, CPB time, aortic crossclamp time, intraoperative urine output; and whether deep hypothermic circulatory arrest, regional cerebral perfusion, or modified ultrafiltration were used.

Primary outcome data consisted of fluid balance for the first 3 postoperative days, which was calculated as the difference between all fluid inputs and outputs as obtained from nursing documentation in 8-hour intervals.

Secondary outcome data included the number of 8-hour shifts until a negative fluid balance, time to extubation, fluid overload, days to sternal closure (for patients with delayed sternal closure), CICU and hospital length of stay, and in-hospital mortality. We also recorded all direct charges assigned to patients more than the standard CICU stay and physician charges in the first 7 postoperative days to assess costs and use of resources. To assess renal laboratory abnormalities, we devised a metabolic abnormality score, which was calculated using morning electrolyte levels in samples drawn routinely on PODs 1 to 5. Scores ranged from 0 to 4 and were calculated by adding 1 point for each of the following abnormalities: hypokalemia (potassium <3 mEq/L), hypochloremia (chloride <90 mEq/L), metabolic alkalosis (bicarbonate >30 mEq/L), and azotemia (blood urea nitrogen >30 mg/dL). We also collected data on the number of doses of medications given to correct the metabolic abnormalities for the first 5 PODs (KCl, arginine hydrochloride, and acetazolamide). Fluid overload was determined by net fluid balance (L)/baseline weight (kg), and reported as a percentile.

To assess inotropic support, we determined the total duration of inotropic support in days and recorded the type and dose of inotropes twice daily on PODs 1 to 3 to calculate inotrope scores as determined by the following calculation: inotrope score = dopamine dose (μg/kg/min) + dobutamine dose (μg/kg/min) + [100 × epinephrine dose (μg/kg/min)] + [10 × milrinone dose (μg/kg/min)] + [10,000 × vasopressin dose (U/kg/min)] + [100 × norepinephrine dose (μg/kg/min)] originally validated in this population by Gaies and colleagues.[13]

Data Collection and Management

Medical records were manually interrogated with assistance from data managers from the Cincinnati Children's Hospital Medical Center Heart Institute Research Core. Outcomes were transferred to a Research Electronic Data Capture (REDCap) database using single data entry with appropriate data cleaning methods before analysis.

Statistical Methods

The median (25th, 75th percentiles) is reported for continuous variables and the Wilcoxon signed rank test was used for comparison between the PDC+ and PDC− groups. Frequency (percentage) is reported for categorical variables and the McNemar exact test was used for comparison